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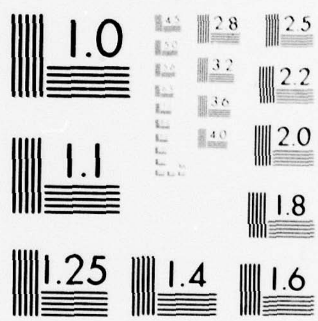

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Components of Human Intelligence

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A theory of human intelligence is presented that is based upon the construct of the component. Components differ in their levels of generality (general, class, specific) and in their functions. Metacomponents are higher-order control processes that are used in planning how a problem should be solved, for making decisions regarding alternative courses of action during problem solving, and for monitoring solution processes. Performance components are processes that are used in the execution of a problem-solving strategy.

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Acquisition components are processes used in learning new information; retention components are processes used in retrieving previously stored information; transfer components are processes used in generalization, that is, in carrying over knowledge from one task or task context to another. A mechanism for interaction among components of different kinds and multiple components of the same kind permits an account of certain interesting aspects of laboratory and everyday problem solving. The article opens with a brief historical overview of alternative basic units for understanding intelligence. Next, it describes one of these units, the component, in some detail, and differentiates among various kinds of components. Examples of each kind of component are given, and the use of each of these components in a problem-solving situation is illustrated. Next, a system of interrelations among the various kinds of components is described. Finally, the functions of components in human intelligence are assessed by considering how components can account for various empirical phenomena in the literature on human intelligence.

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Components of Human Intelligence

Robert J. Sternberg

Yale University

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Abstract

A theory of human intelligence is presented that is based upon the construct of the component. Components differ in their levels of generality (general, class, specific) and in their functions. Metacomponents are higher-order control processes used for planning how a problem should be solved, for making decisions regarding alternative courses of action during problem solving, and for monitoring solution processes. Performance components are processes that are used in the execution of a problem-solving strategy. Acquisition components are processes used in learning new information. Retention components are processes used in retrieving previously stored knowledge. Transfer components are used in generalization, that is, in carrying over knowledge from one task or task context to another. A mechanism for interaction among components of different kinds and multiple components of the same kind permits an account of certain interesting aspects of laboratory and everyday problem solving. The article opens with a brief historical overview of alternative basic units for understanding intelligence. Next, it describes one of these units, the component, in some detail, and differentiates among various kinds of components. Examples of each kind of component are given, and the use of each of these components in a problem-solving situation is illustrated. Next, a system of interrelations among the various kinds of components is described. Finally, the functions of components in human intelligence are assessed by considering how the proposed theory can account for various empirical phenomena in the literature on human intelligence.

Components of Human Intelligence

Theories of human intelligence have traditionally relied upon some basic unit of analysis for explaining sources of individual differences in intelligent behavior. Theories have differed in (a) what this basic unit is proposed to be, in (b) the particular instantiations of this unit that are proposed somehow to be locked inside our heads, and in (c) the way in which these instantiations are organized with respect to one another. Differences in basic units have defined "paradigms" of theory and research on intelligence; differences in instantiations and organizations of these units have defined particular theories within these paradigms. What are these alternative units, and what are the theories that have incorporated them?

Alternative Basic Units for Intelligence

Three alternative basic units for intelligence will be considered: the factor, the S-R bond, and the component (or elementary information process). Each of these basic units leads to a somewhat different conception of what intelligence is and how it is constituted.

The Factor

In most traditional investigations of intelligence, the basic unit of analysis has been the factor. The paradigm in which this unit has been defined and used is referred to as the "differential," "psychometric," or "factorial" paradigm. Factors are obtained by "factor analyzing" a matrix of intercorrelations (or covariances) between scores on tests of measures of ability. Factor analysis tends to group into single factors observable sources of individual-differences variation that are highly correlated with each other, and to group into different factors observable sources of variation that are only modestly correlated with each other. These new groupings are each proposed to represent

unitary, latent sources of individual-differences variation.

What, exactly, is a factor? There is no single, agreed-upon answer to this question. Thurstone (1947) noted that "factors may be called by different names, such as 'causes,' 'faculties,' 'parameters,' 'functional unities,' 'abilities,' or 'independent measurements'" (p. 56). Royce (1963) added to this list "dimensions, determinants, . . . and taxonomic categories" (p. 522), and Cattell (1971) has referred to factors as "source traits."

Instantiations of factors. Factor theorists have differed with respect to the particular factors purported to be basic to intelligence. Spearman (1927) suggested that intelligence comprises one general factor that is common to all of the tasks that are used in the assessment of intelligence, and as many specific factors as there are tasks. The general factor might be viewed as a "common reservoir" that is tapped whenever a person confronts a task requiring intelligent performance. Thurstone (1938) proposed that intelligence is best understood in terms of seven multiple factors, or "primary mental abilities," as he called them: verbal comprehension, word fluency, number, reasoning, spatial visualization, perceptual speed, and memory. Guilford (1967) has proposed a theory encompassing 120 factors formed by crossing five operations, six products, and four contents. Vernon (1971) has suggested a theory consisting of four kinds of factors: the general factor; major group factors, including a verbal-educational factor and a practical-mechanical factor; minor group factors; and specific factors. All of these theorists have relied upon factor analysis for the verification of their theories. Reasons why the same method applied to rather similar data sets can seem to support such widely varying theories are given in Sternberg (1977).

Organizations of factors. The various theories briefly described above contain factors organized in different ways. Spearman's theory is basically

hierarchical, with two levels (of general and specific factors) in the hierarchy. Thurstone's factors might be viewed as overlapping circles (although Thurstone did not himself view them this way). Each factor is viewed as equally important, but the factors are allowed to be modestly correlated with each other. Hence, some of the individual-differences variation in each factor is shared with individual-differences variation in other factors. In Guilford's theory, factors are arranged into a cube, with dimensions of the cube defined by operations, products, and contents of test material. The factors are all alleged to be independent of each other, although it seems unlikely that there would be 120 independent abilities, and evidence in support of the independence of the abilities is meager. Finally, in Vernon's theory, as in Spearman's, factors are organized hierarchically, except that two intermediate levels (of major and minor group factors) have been inserted in the middle of the hierarchy.

<u>The S-R Bond</u>

Stimulus-response (S-R) theorizing has had less influence upon theory and research in intelligence than have the other units we are considering, and hence will be considered more briefly. The role of S-R bonds in theorizing about intelligence can be traced back to Thorndike (Thorndike, 1911; Thorndike, Bregman, Cobb, & Woodyard, 1928). Thorndike, like subsequent S-R theorists, viewed intelligence primarily in terms of the ability to learn. In early S-R theorizing, intelligence was understood in terms of the buildup of simple S-R bonds. A more sophisticated and variegated view has been proposed by Gagné (1970), who has suggested that there are eight kinds of learning, which differ among themselves in both the quantity and quality of S-R bonds involved. The simplest kind of learning, signal learning, involves the establishment of conditioned responses of the kind studied in traditional Pavlovian conditioning paradigms. Slightly more complex is stimulus-response learning, or operant

conditioning of the kind found in typical Skinnerian paradigms, and in the simple paradigms suggested earlier by Thorndike (1911). Chaining, a third kind of learning, occurs when simple S-R bonds are linked together into sequences, or chains. The fourth type of learning, verbal association, is veiwed as a subvariety of chain learning in which the chains contain verbal S-R elements. Discrimination learning, a fifth type of learning, involves learning not only chain formations, but the discrimination of one chain from another, so that a response that is eventually made is based upon the appropriate chain and no other. Concept learning, a sixth kind of learning, differs from the previous kinds of learning in that behavior is controlled by abstract properties of stimuli, rather than by the stimuli themselves. The seventh kind of learning in the theory is rule learning, which occurs as the result of the formation of a chain of two or more concepts. Thus, in a sense, rule learning is to concept learning what chaining is to stimulus-response learning. The last kind of learning, problem solving, occurs when a learner combines rules he or she already has learned into novel, higher-order rules.

Gagné's theory is of interest to students of intelligence because it carries the notion of the S-R bond much further than this notion has been carried by previous S-R theories, which were oriented primarily toward simpler forms of behavior. Despite the extension of the theory to behavior as complex as problem solving, however, the influence of Gagné's theory upon current research on intelligence is relatively small, perhaps because research on intelligence requires the extension of the S-R construct beyond the sphere in which the construct has maximum explanatory and heuristic power. Although useful in accounts of simple learning, the S-R construct seems to be less useful in accounts of highly complex kinds of learning.

The Component

A component is an elementary information process that operates upon internal representations of objects or symbols (Sternberg, 1977; see also Newell & Simon, 1972). The component may translate a sensory input into a conceptual representation, transform one conceptual representation into another, or translate a conceptual representation into a motor output. What is considered elementary enough to be labeled a component depends upon the level of theorizing that is desired. Just as factors can be split into successively finer subfactors, so can components be split into successively finer subcomponents. Thus, no claim is made that any of the components referred to later in this article are elementary at all levels of analysis. Rather, they are claimed to be elementary at a convenient level of analysis. The same caveat applies to the typology of components proposed. Doubtless, other typologies could be proposed that would serve the present or other theoretical purposes as well or better. The particular typology proposed, however, has proved to be convenient in at least certain theoretical and experimental contexts.

The remainder of this article will be devoted to an exploration of the concept of the component.[1] The discussion will be divided into four sections. The first will deal with properties of components; the second will deal with kinds of components; the third will deal with interrelations among kinds of components; and the fourth will deal with the relations between components and general intelligence.

Properties of Components

Each component has three important properties associated with it: duration, difficulty (i.e., error probability), and probability of execution. These three properties are, in principle, independent. For example, a given component may take a rather long time to execute, but may be rather easy to execute, say, in

the sense that its execution rarely leads to an error in solution; or the component may be executed quite rapidly, and yet be rather difficult to execute, say, in the sense that its execution often leads to an error in solution (see Sternberg, 1977).

Consider "mapping," one component in solving analogies, for example, LAWYER is to CLIENT as DOCTOR is to (a) PATIENT, (b) MEDICINE. Mapping requires discovery of the higher order relation between the first and second halves of the analogy. The component has a certain probability of being executed in solving an analogy. If executed, it has a certain duration and a certain probability of being executed correctly (Sternberg, 1977).

Kinds of Components

Kinds of components can be classified in two different ways: by function and by level of generality.

Function

Components perform (at least) five kinds of functions. Metacomponents are higher-order control processes that are used for planning how a problem should be solved, for making decisions regarding alternative courses of action during problem solving, and for monitoring solution processes. Performance components are processes that are used in the execution of a problem-solving strategy. Acquisition components are processes used in learning new information. Retention components are processes used in retrieving previously stored knowledge. Transfer components are used in generalization, that is, in carrying over knowledge from one task or task context to another.

Metacomponents.[2] Metacomponents are specific realizations of control processes that are sometimes collectively (and loosely) referred to as the "executive" or the "homunculus." I have identified six metacomponents that I believe are general in intellectual behavior (Sternberg, Note 1), that is, that

are "general components."

1. Selection of lower-order components. An individual must select a set of lower-order (performance, acquisition, retention, or transfer) components to use in the solution of a given task. Various overlapping sets of components may be sufficient for the solution of a task, but only a small subset of these components may be necessary for the solution of that task. The choice of additional components may affect the efficacy with which the task is accomplished, and the ultimate outcome of the task solution. In some instances, choice of components will be partially attributable to differential availability or accessibility of various components. For example, young children may lack certain components that are necessary or desirable for the accomplishment of particular tasks, or may not yet execute these components in a way that is efficient enough to facilitate task solution. Sternberg and Rifkin (1979), for example, tested children in grades 2, 4, and 6, as well as adults, in their respective abilities to solve simple analogy problems. They found that the performance component used to form the higher-order relation between the two halves of the analogy (mapping) was used by adults and by children above the second grade. The authors suggested that the unavailability or inaccessibility of this component in very young children necessitates a rather radical shift in the way the analogy problems are solved by these children, relative to the way the problems are solved by older children and adults.

2. Selection of one or more representations or organizations for information. A given component is often able to operate upon any one of a number of different possible representations or organizations for information. The choice of representation or organization can facilitate or impede the efficacy with which the component operates. Sternberg and Weil (in press) found that the optimal representation for information in the linear-syllogisms task, for

example, John is taller than Bill; Bill is taller than Pete; who is tallest?, can be linguistic, spatial, or both linguistic and spatial, depending upon individual subjects' patterns of abilities. In solving problems, the optimal form of representation for information may depend upon item content. In some cases, for example, geometric analogies, an attribute-value representation may be best. In other cases, for example, animal-name analogies, a spatial representation may be best (Sternberg, 1977; Sternberg & Gardner, Note 2). Thus, the efficacy of a form of representation can be determined either by subject variables, by task variables, or by the interactions between them.

3. Selection of a strategy for combining lower-order components. In itself, a list of components is insufficient to perform a task. One needs also to sequence these components in a way that facilitates task performance, to decide how nearly exhaustively each component will be performed, and to decide which components to execute serially and which to execute in parallel. In an analogies task, for example, alternative possible strategies for problem solving differ in terms of which components are exhaustive and which are self-terminating. The exhaustively-executed components result in comparison of all possible encoded attributes or dimensions linking a pair of terms (such as LAWYER and CLIENT, or DOCTOR and PATIENT). The components executed with self-termination result in comparison of only a subset of the attributes that have been encoded. The individual must decide which comparisons are to be done exhaustively, and which are to be done with self-termination (Sternberg, 1977).

4. Decision as to consistency with which a strategy should be executed. It is often not obvious or even ascertainable in advance what strategy will best solve a given class of problems; this information may become available only after the individual gains some experience with the class of problems. Thus, the individual must decide how long to wait before settling upon a strategy. Moreover,

once a strategy is settled upon, it may cease to be optimal after practice in solving the kind of problem to which the strategy is applied. Johnson-Laird (1972), for example, has suggested that the optimal strategy for solving linear syllogisms may change as a function of practice; as it turns out, though, evidence that this strategy change actually occurs in subjects' solutions of linear syllogisms is marginal at best (Sternberg, in press - b). One change that seems quite likely to occur in many kinds of information processing, however, is a change from more controlled to more automatic processing (Shiffrin & Schneider, 1977).

5. Decision regarding speed-accuracy tradeoff. All tasks and components of tasks can be allotted only limited amounts of time, and greater restrictions on the time allotted to a given task or task component may result in a reduction in quality of performance. One must therefore decide how much time to allot to each component of a task, and how much the time restriction will affect the quality of performance for that particular component. One tries to allot time across the various components of task performance in a way that maximizes the quality of the entire product. Payoffs for various speed-accuracy tradeoffs can be determined by both internal and external factors. Thus, some individuals seem to have impulsive styles of working, almost without regard to the external consequences of this style; others seem always to adopt a slower, reflective style. Sometimes, a task can be constructed so that subjects develop an expectation about it, almost without regard to what they are told about the task. For example, in an as yet unpublished experiment, Miriam Schustack and I presented subjects with analogies grouped into booklets of 24 items apiece. We discovered (to our chagrin) that subjects tried to complete the booklets, no matter what they were told regarding experimenters' expectations concerning the amount of work they could be expected to complete in the time period allotted.

When the same items were re-presented tachistoscopically, the expected speed-accuracy tradeoffs did occur.

6. Solution monitoring. As individuals proceed through a problem, they must keep track of what they have already done, what they are currently doing, and what they still need to do. The relative importance of these three items of information differs across problems. If things are not progressing as expected, an accounting of one's progress may be needed, and the possibility may need to be considered that one should change one's goals. Often, new, more realistic goals need to be formulated as a person realizes that the old goals cannot plausibly be reached. In solving analogies and other kinds of problems, for example, individuals sometimes find that none of the presented answer options provides a satisfactory answer to the problem. The individual must then decide whether to re-perform certain processes that might have been performed erroneously, or to choose the best of the available, if nonoptimal, answer options (Sternberg, 1977).

Performance components.[3] Performance components are used in the execution of various strategies for task performance. The number of possible performance components is rather large, as would have to be the case for people to perform a variety of tasks in a versatile fashion. Many of these components probably apply only to small or uninteresting subsets of tasks, and hence deserve little attention. As examples of performance components, consider some components that are quite broad, those used in analogical and other kinds of inductive reasoning and problem-solving tasks (Sternberg, 1977; Sternberg & Gardner, Note 2).

1. Encoding. In any problem-solving situation, a person must encode the terms of the problem, storing them in working memory and retrieving from long-term memory information relating to these problem terms. Consider, for example,

the analogy cited earlier, LAWYER is to CLIENT as DOCTOR is to (a) PATIENT, (b) MEDICINE. The person must retrieve from long-term memory attributes of LAWYER such as "professional person," "law-school graduate," and "member of the bar," and place these attributes in working memory.

2. Inference. In inference, a person detects one or more relations between two objects, both of which may be either concrete or abstract. In the analogy, the person detects relations between LAWYER and CLIENT, such as that a lawyer provides professional services to a client.

3. Mapping. In mapping, a person relates aspects of a previous situation to aspects of a present one. In an analogy, the person seeks the higher-order relationship between the first half of the analogy (the previous situation) and the second half of the analogy (the present situation). In the example, both halves of the analogy deal with professional persons.

4. Application. In application, a person uses the relations between past elements of the situation and the decision made to help him or her make the present decision. In the example, the person seeks to find an option that is related to DOCTOR in the same way that CLIENT was related to LAWYER.

5. Justification. In justification, the individual seeks to verify the better or best of the presented answer options. In the example, PATIENT may not be viewed as a perfect analogue to CLIENT, since a patient may be viewed as a type of client, but not vice versa; but PATIENT is clearly the better of the two options.

6. Response. In response, the person communicates a solution to the problem. In the present example, the person communicates selection of the option, PATIENT.

Acquisition, retention, and transfer components.[4] Acquisition components are skills involved in learning new information; retention components are skills

involved in retrieving information that has been previously acquired; transfer components are skills involved in generalizing retained information from one situational context to another. New information is always presented in some kind of a context, no matter how impoverished. We believe that acquisition components represent particular skills involved in utilizing context cues to learn new information, that retention components represent particular skills involved in retrieving these cues at time of retention (see also Tulving & Thomson, 1973), and that transfer components represent particular skills involved in relating old contexts to new contexts. The contextual cues exploited in the three kinds of components are probably highly overlapping; people's abilities to use these kinds of cues in the three kinds of situations, however, may be highly variable. Suppose, for example, we are interested in a person's acquisition, retention, and transfer of information in dealing with unfamiliar words and their meanings. What are some of the components that might be involved in these three aspects of information processing?

1. Number of occurrences of target information. Certain aspects of a kind of situation will recur in virtually every instance of that kind of situation; others will occur only rarely. Higher acquisition, retention, and transfer of information would be expected from those aspects of a kind of situation that recur with greater regularity. In the example, the more times a new and originally unfamiliar word is seen, the more likely an able person is to acquire, retain, or transfer its meaning.

2. Variability in contexts for presentation of target information. Some kinds of information about a given kind of situation will be available in multiple contexts, whereas other kinds of information may be available only in single or very limited contexts. Higher acquisition, retention, and transfer of information would be expected from aspects of a situation that are presented

in more highly variable contexts. For example, the more variable the contexts are in which a previously unfamiliar word is presented, the more likely one is to acquire, retain, or transfer its meaning.

3. Importance of target information to overall situation. Some kinds of information about a given kind of situation will be central to that situation and decisions made about it; other kinds of information will be peripheral, and have only a minor impact upon subsequent decisions. Higher acquisition, retention, and transfer of information would be expected from those aspects of a kind of situation that are central to that situation. For example, the more important the meaning of a previously unfamiliar word is to understanding the passage in which it occurs, the better the context is for acquiring, retaining, and transferring the word's meaning.

4. Recency of occurrence of target information. Certain information about a situation may have occurred more recently in one's experience, whereas other information may have occurred in one's experience in the more distant past. Higher retention of information would be expected from those aspects of a kind of situation that have occurred in one's more recent experience. If, for example, a previously unfamiliar word has been recently encountered, one is more likely to retain its meaning.

5. Helpfulness of context to understanding of target information. Certain kinds of information may be presented in contexts that facilitate their acquisition, retention, and transfer; other kinds of information may be presented in less facilitative contexts. Higher acquisition, retention, and transfer would be expected in those cases where context is more facilitating. For example, the more the context in which a new word occurs provides clues as to that word's meaning, the more one is likely to acquire, retain, and transfer the word's meaning.

6. <u>Helpfulness of stored information to understanding target information</u>. Previously stored information can facilitate acquisition, retention, and transfer of new information. Higher learning, retention, and transfer would be expected in those cases where information learned in the past can be brought to bear upon the present information, providing a context that may not be contained in the new learning situation itself. For example, if one recognizes a Latin root in an unfamiliar word, one is more likely to acquire, retain, and transfer the meaning of that word.

The task and situational variables described above exemplify the functions served by the various kinds of components, but are by no means an exhaustive listing of the relevant variables in acquisition, retention, and transfer. Moreover, they are at a level of analysis that may be convenient for some purposes, but not for others. In some circumstances, at least, they provide convenient units for understanding differences in item or task difficulty, and for understanding differences among subjects in quality of information acquisition, retention, and transfer.

<u>Level of Generality</u>

Components can be classified in terms of three levels of generality. <u>General components</u> are required for performance of all tasks within a given task universe; <u>class components</u> are required for performance of a proper subset of tasks that includes at least two tasks within the task universe; and <u>specific components</u> are required for the performance of single tasks within the task universe. Tasks requiring intelligent performance differ in the numbers of components they require for completion and in the number of each kind of component they require.

Consider, again, the example of an analogy. "Encoding" seems to be a general component, in that it is needed in the solution of problems of all

kinds--the problem cannot be solved unless its terms are encoded in some manner. "Mapping" seems to be a class component, in that it is required for the solution of certain kinds of induction problems. But it is certainly not needed in problems of all kinds. No task-specific components have been identified in analogical reasoning, which is perhaps why analogies serve so well in tests of general intellectual functioning.

Interrelations among Kinds of Components

Kinds of components are interrelated in various ways. We shall consider first how components serving different functions are interrelated, and then how components of different levels of generality are interrelated. Since levels of generality and functions are completely crossed, the interrelations among components of differing levels of generality apply to all of the functionally different kinds of components, and the interrelations among the functionally different kinds of components apply at all levels of generality.

Function

The interrelations among the functionally different kinds of components are shown in Figure 1. The different kinds of components are closely related, as would be expected in an integrated, intelligent system. Four kinds of interrelations need to be considered. Direct activation of one kind of component

Insert Figure 1 about here

by another is represented by solid double arrows. Indirect activation of one kind of component by another is represented by single solid arrows. Direct feedback from one kind of component to another is represented by single broken arrows. Indirect feedback from one kind of component to another proceeds from and to the same components as does indirect activation, and so is shown by the single solid arrows. Direct activation or feedback refers to the immediate

passage of control or information from one kind of component to another. Indirect activation or feedback refers to the mediate passage of control or information from one kind of component to another via a third kind of component.

In the proposed system, only metacomponents can directly activate and receive feedback from each other kind of component. Thus, all control to the system passes directly from the metacomponents, and all information from the system passes directly to the metacomponents. The other kinds of components can activate each other indirectly, and receive information from each other indirectly; in every case, mediation must be supplied by the metacomponents. For example, acquisition of information affects retention of information and various kinds of transformations (performances) upon that information, but only via the link of the three kinds of components to the metacomponents. Information from the acquisition components is filtered to the other kinds of components through the metacomponents.

Consider some examples of how the system might function in the solution of a word puzzle, such as an anagram (scrambled word). As soon as one decides upon a certain tentative strategy to try unscrambling the letters of the word, activation of that strategy can pass directly from the metacomponent responsible for deciding upon a strategy to the performance component responsible for executing the first step of the strategy, and subsequently, activation can pass to the successive performance components needed to execute the strategy. Feedback will return from the performance components indicating how successful the strategy is turning out to be. If monitoring of this feedback indicates lack of success, control may pass to the metacomponent that is "empowered" to change strategy; if no successful change in strategy can be realized, the solution monitoring metacomponent may change the goal altogether.

As a given strategy is being executed, new information is being acquired about how to solve anagrams, in general. This information is also fed back to the metacomponents, which may act upon or ignore this information. New information that seems useful is more likely to be directed back from the relevant metacomponents to the relevant retention components for retention in long-term memory. What is acquired does not directly influence what is retained, however, so that "practice does not necessarily make perfect": Some people may be unable to profit from their experience because of inadequacies in metacomponential information processing. Similarly, what is retained does not directly influence what is later transferred. The chances of information being transferred to a later context will be largely dependent upon the form in which the metacomponents decided to store the information for later access. Acquired information also does not directly affect transformations (performances) upon that information. The results of acquisition (or retention or transfer) must first be fed back into the metacomponents, which in effect decide what information will filter back indirectly from one type of component to another.

The metacomponents are able to process only a limited amount of information at a given time. In a difficult task, and especially a new and difficult one, the amount of information being fed back to the metacomponents may exceed their capacity to act upon this information. In this case, the metacomponents become overloaded, and valuable information that cannot be processed may simply be wasted. The total information-handling capacity of the metacomponents of a given system will thus be an important limiting aspect of that system. Similarly, capacity to allocate attentional resources so as to minimize the probability of bottlenecks will be part of what determines the effective capacity of the system (see also Hunt, Note 3).

Figure 1 does not show interrelations among various individual members of each single functional kind of component. These interrelations can be easily described in words, however. Metacomponents are able to communicate with each other directly, and to activate each other directly. It seems likely that there exists at least one metacomponent (other than those described earlier in the article) that controls intercommunication and interactivation among the other metacomponents, and there is a certain sense in which this particular metacomponent might be viewed as a "meta-metacomponent." Other kinds of components are not able to communicate directly with each other, however, or to activate each other. But components of a given kind can communicate indirectly with other components of the same kind, and can activate them indirectly. Indirect communication and activation proceed through the metacomponents, which can direct information or activation *from* one component to another component of the same kind.

This description of the interrelations among the various kinds of components is obviously a mere sketch of a functioning system, and it leaves many questions about the functioning of the system unanswered. Nevertheless, it seems to serve as a start toward specifying one form an intelligent system might take.

Level of Generality

Components of varying levels of generality are related to each other through the ways in which they enter into the performance of tasks (Sternberg, 1979b). Figure 2 shows the nature of this relationship, which is hierarchical.

Insert Figure 2 about here

Each node of the hierarchy contains a task, which is designated by a roman or arabic numeral or by a letter. Each task comprises a set of components at the

general (g), class (c), and specific (s) levels. In the figure, "g" refers to a set of general components; "c_i" and "c_j" each refer to a set of class components, whereas "c_{ij}" refers to a concatenated set of class components that includes the class components from both c_i and c_j; and "s_i" refers to a set of specific components. The levels of the hierarchy differ in terms of the complexity of the tasks assigned to them. More complex tasks occupy higher levels of the hierarchy; simpler tasks occupy lower levels. The complexity of a task is defined here in terms of the number and identities of the class components contained in the task: The more sets of class components that are concatenated in a particular task, the more complex that task is.

At the bottom of the hierarchy are very simple tasks (IA1, IA2, IB1, IB2), each of which requires a set of general, class, and specific components for its execution. At one extreme, the general components are the same in all four tasks (and in all of the tasks in the hierarchy), in that a general component is by definition one that is involved in the performance of every task in the universe (here expressed as a hierarchy) of interest. At the other extreme, the specific components are unique to each task at this (and every other) level, in that a specific component is by definition one that is relevant to only a single task. The class components are also not shared across tasks at this level: Task IA1 has one set of class components; Task IA2 another; Task IB1 another; and Task IB2 yet another. As examples, Task IA1 might be series completions (e.g., 2, 4, 6, 8, ?), Task IA2 metaphorical ratings (e.g., how good a metaphor is "The moon is a ghostly galleon"?), Task IB1 linear syllogisms (e.g., N is higher than P; P is higher than L; which is highest?), and Task IB2 categorical syllogisms (e.g., All C are B; some B are A; can one conclude that some C are A?).

Consider next the middle level of the hierarchy, containing Tasks IA and IB. Tasks IA and IB both share with the lower-order tasks, and with each other, all of their general components but none of their specific components. What distinguishes Tasks IA and IB from each other, however, and what places them in their respective positions in the hierarchy, is the particular set of class components they each contain. The class components involved in the performance of Task IA represent a concatenation of the class components involved in the performance of Tasks IA1 and IA2; the class components involved in the performance of Task IB represent a concatenation of the class components involved in the performance of Tasks IB1 and IB2. Tasks IA and IB contain no common class components, however. For example, Task IA might be analogies, which require a concatenation of the class components from series completions and metaphorical ratings. Task IB might be the higher-order task of quantified linear syllogisms (e.g., All _H_ are higher than all _Q_; some _Q_ are higher than all _Z_; can one conclude that some _H_ are higher than some _Z_?), which requires a concatenation of class components from linear and categorical syllogisms.

Finally, consider the task at the top level of the hierarchy, Task I. Like all tasks in the hierarchy, it shares general components with all other tasks in the hierarchy, but shares specific components with none of these tasks (again, since these components are by definition task-specific). Performance on this task is related to performance on Tasks IA and IB through the concatenation of class components from these two tasks. In the present example, Task I might be inductive syllogisms, which require a person to induce the premises of a syllogism and then to solve the syllogism. Scientific reasoning is often of this kind: One must induce regularities from empirical data, and then deduce properties of these regularities.

According to the present view, many kinds of tasks are hierarchically interrelated to each other via components of information processing. The proposed hierarchical model shows the nature of these interrelationships. It should be made clear just what is arbitrary in this hierarchical arrangement and what is not. The arrangement does not prespecify the degrees of differentiation between the top and bottom levels of the hierarchy, nor where the hierarchy should start and stop. As was stated earlier, the level that is defined as "elementary" and thus suitable for specification of components is arbitrary: What is a component in one theory might be a subcomponent in another, or a task in still another. The level of specification depends upon the purpose of the theory being considered. Theories at different levels serve different purposes, and must be justified in their own right. But certain important aspects of the arrangement are nonarbitrary. The vertical order of tasks in the hierarchy, for example, is not subject to permutation, and although whole branches of the hierarchy (from top to bottom) can be permuted (the left side becoming the right side and vice versa), individual portions of those branches cannot be permuted. For example, IA and IB cannot be switched unless the tasks below them are switched as well. In other words, horizontal reflection of the whole hierarchy is possible, but horizontal reflection of selected vertical portions is not possible. These nonarbitrary elements of the hierarchy make disconfirmation of a given theory both possible and feasible. A given hierarchy can be found to be inadequate if the various constraints outlined above are not met. In many instances, the hierarchy may simply be found to be incomplete, in that branches or nodes of branches may be missing and thus need to be filled in.

To summarize, the structural model serves as a basis for interrelating the tasks and components in a given theoretical system. The model does not

specify what these tasks or components should be, nor does it specify how coarsely or finely the tasks and components should be defined.

Relations between Components and General Intelligence

On the componential view, components causally account for a substantial part of what we consider to be general intelligence. If one takes a broad view of general intelligence as capturing all of those aspects of behavior that contribute to effectiveness of adaptation to everyday living, there may well be major parts of intelligence that are not accounted for within the componential framework. Nevertheless, components are perhaps able to account for an interesting portion of what we call "intelligent behavior." Consider some of the key phenomena described in the textbook literature on intelligence (e.g., Brody & Brody, 1976; Butcher, 1968; Cronbach, 1970; Vernon, 1979), and how they would be explained within the componential framework. Some of these phenomena have actually appeared to be mutually incompatible, but no longer appear so when viewed through the "lens" of the componential framework.

1. There appears to be a construct of "general intelligence." Various sorts of evidence have been adduced in support of the existence of general intelligence. The most persuasive sort of evidence, in some ways, is everyday experience: Casual observation in everyday life suggests that some people are "generally" more intelligent than others. People's rank orderings of each other may differ according to how they define intelligence, but some rank ordering is usually possible. Historically, the evidence that has been offered most often in favor of the existence of general intelligence is the appearance of a general factor in unrotated factor solutions from factor analyses of tests used to measure intelligence (e.g., Spearman, 1927). In itself, this evidence is not persuasive, because factor analysis of any battery of measures will yield a general factor if the factors are not rotated: This is a mathematical

rather than a psychological outcome of factor analysis. However, the psychological status of this outcome is bolstered by the fact that an analogous outcome appears in information-processing research as well: Information-processing analyses of a variety of tasks have revealed that the "regression constant" is often the individual-differences parameter most highly correlated with scores on general intelligence tests (see Sternberg, 1979b). This constant measures variation that is constant across all of the item or task manipulations that are analyzed via multiple regression. The regression constant seems to bear at least some parallels to the general factor.

The strongest evidence that has been offered against the existence of a construct of general intelligence is that some rotations of factors fail to yield a general factor. But this failure to find a general factor in certain kinds of rotated solutions is as much determined by mathematical properties of the factorial algorithm as is the success in finding a general factor in an unrotated solution. Moreover, if the multiple factors are correlated, and if they are themselves factored, they will often yield a "second-order" general factor.

In componential analysis, individual differences in general intelligence are attributed to individual differences in the effectiveness with which general components are performed. Since these components are common to all of the tasks in a given task universe, factor analyses will tend to lump these general sources of individual-differences variance into a single general factor. As it happens, the metacomponents have a much higher proportion of general components among them than do any of the other kinds of components, presumably because the executive routines needed to plan, monitor, and possibly replan performance are highly overlapping across tasks of a widely differing nature. Thus, individual differences in metacomponential functioning are largely

responsible for the persistent appearance of a general factor.

Metacomponents are probably not solely responsible for "*g*," however. Most behavior, and probably all of the behavior exhibited on intelligence tests, is learned. There may be certain acquisition components general across a wide variety of learning situations, which also enter into the general factor. Similarly, components of retention and transfer may also be common to large numbers of tasks. Finally, certain aspects of performance--such as encoding and response--are common to virtually all tasks, and they, too, may enter into the general factor. Therefore, although the metacomponents are primarily responsible for individual differences in general intelligence, they are probably not solely responsible.

2. A general factor does not appear in "simple-structure" rotations of factor analyses; instead, a set of "primary mental abilities" appears. As noted above, the appearance of one or another kind of sets of factors is largely a mathematical property of factor analysis and the kind of rotation used. If one views factors as causal entities, as do most adherents to the traditional psychometric approach to intelligence, then one becomes involved in a seemingly irresoluble debate regarding which is the "correct" rotation of factors. Mathematically, all rigid rotations of a set of factor axes are permissible; and there seems to be no agreed-upon psychological criterion for choosing any "correct" rotation. In componential analysis, the choice of a criterion for rotation is arbitrary—a matter of convenience. Different rotations serve different purposes. The unrotated solution considered above, for example, is probably ideal for isolating a composite measure of individual differences in effectiveness of performance of general components. Consider next what is probably the most popular orientation of factorial axes among American psychometricians, that obtained by Thurstonian rotation to simple structure. Such a rotation has tended

to yield a set of "primary mental abilities," such as verbal comprehension, word fluency, number, spatial relations, perceptual speed, memory, and reasoning (see Thurstone, 1938). The simple-structure rotation, like the unrotated solution, has somehow seemed "special" to psychometricians for many years, and I believe that it may be, in a sense, "special." Whereas the unrotated solution seems to provide the best composite measure of general components, my inspections of various rotated solutions have led me to believe that simple-structure rotations tend to provide the "best" measures of class components—best in the sense that there is minimal overlap across factors in the appearances of class components. A simple-structure rotation distributes the general components throughout the set of factors so that the same general components may appear in multiple factors: Such factors, therefore, will necessarily be correlated. But I believe the low to moderate correlations are due for the most part to overlap among general components: The class components found at a fairly high level of generality seem to be rather well restricted to individual factors. Given that the factorial model of primary mental abilities originally proposed by Thurstone was nonhierarchical, there will have to be some overlap across factors in class components; but for theoretical and practical purposes, this overlap seems to be minimized. Thus, neither the unrotated solution of Spearman and others nor the simple-structure solution of Thurstone and others is "correct" to the exclusion of the other. Each serves a different theoretical purpose and possibly a different practical purpose as well: The factorial theory of Spearman is useful when one wishes the most general, all-purpose predictor possible; the factorial theory of Thurstone is useful when one wishes differential prediction, for example, between verbal and spatial performance.

3. <u>In hierarchical factor analyses, there seem to be two very broad group factors (or general subfactors), sometimes referred to as crystallized ability</u>

and fluid ability. The crystallized-fluid distinction has been proposed by Cattell and Horn (see Cattell, 1971, for a detailed description), and a similar distinction has been proposed by Vernon (1971). Crystallized ability is best measured by tests that measure the products of acculturation: vocabulary, reading comprehension, general information, etc. Fluid ability is best measured by tests of abstract reasoning: visual analogies, visual classifications, visual series completions, etc. (Verbal items are also useful for this purpose if their vocabulary level is kept low.) Once again, I believe that there is something special about this particular hierarchical solution. Crystallized ability tests seem best to separate the products of acquisition, retention, and transfer components. I say "products," because crystallized ability tests measure outcomes of these component processes, rather than the operations as they are actually executed. The vocabulary that is measured by a vocabulary test, for example, may have been acquired years ago. Fluid ability tests, on the other hand, seem best to separate the execution of performance components. These tests seem heavily dependent upon a rather small set of performance components (Sternberg, 1979b; Sternberg & Gardner, Note 2), in particular, those mentioned earlier in this article. Thus, dividing factors along the crystallized-fluid dimension seems to provide a good distinction between the products of acquisition, retention, and transfer components on the one hand, and the current functioning of performance components on the other. Crystallized and fluid factors will be correlated, however, because of shared metacomponents.

Horn (1968) has found that crystallized ability generally continues to increase throughout one's lifetime, whereas fluid ability first increases, then levels off, and finally decreases. I would like to suggest that the contrast between the continued increase in crystallized ability with age and the increase followed by decrease in fluid ability with increasing age is due less to the

kinds of abilities measured than to the ways in which the respective abilities are measured. Crystallized ability tests measure primarily accumulated products of components; fluid ability tests measure primarily current functioning of components. I think it likely that current functioning decreases after a certain age level, whereas the accumulated products of these components are likely to continue to increase (at least until senility sets in). Were one to measure current functioning of acquisition, retention, and transfer components--e.g., by tests of acquisition of knowledge presented in context—rather than the products of these components, I suspect the ability curve would show a pattern of rise and fall similar to that shown on standard fluid ability tests.

4. Procrustean rotation of a factorial solution can result in the appearance of a large number of "structure-of-intellect" factors. Procrustean rotation of a factorial solution involves rotation of a set of axes into maximum correspondence with a predetermined theory regarding where the axes should be placed. Guilford (1967) has used Procrustean rotation to support his "structure-of-intellect" theory. According to this theory, intelligence comprises 120 distinct intellectual aptitudes, each represented by an independent factor. Horn and Knapp (1973) have shown that comparable levels of support can be obtained via Procrustean rotation to randomly determined theories. The viability of Guilford's theory is therefore open to at least some question. Nevertheless, I believe that there probably is a psychological basis for at least some aspects of Guilford's theory, and that these aspects of the theory can be interpreted in componential terms.

A given component must act upon a particular form of representation for information, and upon a particular type of information (content). The representation, for example, might be spatial or linguistic; the type of information

(content) might be an abstract geometric design, a picture, a symbol, a word, etc. Forms of representations and contents, like components, can serve as sources of individual differences: A given individual might be quite competent when applying a particular component to one kind of content, but not when applying it to another. Representation, content, and process have been largely confounded in most factorial theories, probably because certain components tend more often to operate upon certain kinds of representations and contents, and other components tend more often to operate upon different kinds of representations and contents. This confounding serves a practical purpose, that of keeping to a manageable number the factors appearing in a given theory or test. But it does obscure the probably partially separable effects of process, representation, and content. Guilford's theory provides some separation, at least between process and content. I doubt the product dimension has much validity, other than through the fact that different kinds of products probably involve slightly different mixes of components. On the one hand, the theory points out the potential separability of process and content. On the other hand, it does so at the expense of manageability. Moreover, it seems highly unlikely that the 120 factors are independent, as they will show overlaps, at minimum, in shared metacomponents.

The distinction among process, content, and representation is an important one to keep in mind, because it is in part responsible for the low intercorrelations that are often obtained between seemingly highly related tasks. Two tasks (e.g., verbal analogies and geometric analogies) may share the same information-processing components, yet show only moderate correlations because of content and representational differences. Guilford's finding of generally low intercorrelations between ability tests is probably due in part to the wide variation in the processes, contents, and representations required for

solution of his various test items.

5. <u>The best single measure of overall intelligence (as measured by intelligence tests) is vocabulary</u>. This result (see, e.g., Matarazzo, 1972) has seemed rather surprising to some, because vocabulary tests seem to measure acquired knowledge rather than intelligent functioning. But the above discussion should adumbrate why vocabulary is such a good measure of overall intelligence. Vocabulary is acquired incidentally throughout one's life span as a result of acquisition components; the vocabulary that is retained long enough to be of use on a vocabulary test has also been successfully processed by a set of retention components. And for the vocabulary to be retained and recognized in the particular context of the vocabulary test, it probably also had to be processed successfully by transfer components. Moreover, for all of these kinds of components to operate effectively, they must have been under the control of metacomponents. Thus, vocabulary provides a very good, although indirect, measure of the lifetime operations of these various kinds of components. Vocabulary has an advantage over many kinds of performance tests, which measure the functioning of performance components only at the time of testing. These latter kinds of tests are more susceptible to the day-to-day fluctuations in performance that create unreliability and, ultimately, invalidity in tests. Because performance components are not particularly critical to individual differences in scores on vocabulary tests, one would expect vocabulary test scores to be less highly correlated with performance types of tests than with other verbal tests, and this is in fact the case (see Matarazzo, 1972).

This view of the nature of vocabulary tests in particular, and of tests of verbal ability in general, differs from that of Hunt, Lunneborg, and Lewis (1975). These authors have sought to understand individual differences in

verbal ability in terms of individual differences in performance components involved in relatively simple information-processing tasks used in laboratories of experimental psychologists. They suggest, for example, that a major element of verbal ability is speed of accessing simple verbal codes in short-term memory. This framework is not necessarily incompatible with that presented here: The two views may highlight different aspects of verbal comprehension.

6. <u>The absolute level of intelligence in children increases with age.</u> Why do children grow smarter as they grow older? The system of interrelations among components depicted in Figure 1 seems to contain a dynamic mechanism whereby cognitive growth can occur.

First, the components of acquisition, retention, and transfer provide the mechanisms for a steadily developing knowledge base. Increments in the knowledge base, in turn, allow for more sophisticated forms of acquisition, retention, and transfer, and possibly for greater ease in execution of performance components. For example, some transfer components may act by relating new knowledge to old knowledge. As the base of old knowledge becomes deeper and broader, the possibilities for relating new knowledge to old knowledge, and thus for incorporating that new knowledge into the existing knowledge base, increase. There is thus the possibility of an unending feedback loop: The components lead to an increased knowledge base, which leads to more effective use of the components, which leads to further increases in the knowledge base, and so on.

Second, the self-monitoring metacomponents can, in effect, learn from their own mistakes. Early on, allocation of metacomponential resources to varying tasks or kinds of components may be less than optimal, with resulting loss of valuable feedback information. Self-monitoring should eventually result in improved allocations of metacomponential resources, in particular,

to the self-monitoring of the metacomponents. Thus, self-monitoring by the metacomponents results in improved allocation of metacomponential resources to the self-monitoring of the metacomponents, which in turn leads to improved self-monitoring, and so on. Here, too, there exists the possibility of an unending feedback loop, one that is internal to the metacomponents themselves.

Finally, indirect feedback from kinds of components other than metacomponents to each other and direct feedback to the metacomponents should result in improved effectiveness of performance. Acquisition components, for example, can provide valuable information to performance components (via the metacomponents) concerning how to perform a task, and the performance components, in turn, can provide feedback to the acquisition components (via the metacomponents) concerning what else needs to be learned in order to perform the task optimally. Thus, other kinds of components, too, can generate unending feedback loops in which performance improves as a result of interactions between the kinds of components, or between multiple components of the same kind.

There can be no doubt that the major variables in the individual-differences equation will be those deriving from the metacomponents. All feedback is filtered through those elements, and if they do not perform their function well, then it won't matter very much what the other kinds of components can do. It is for this reason that the metacomponents are viewed as truly central in understanding the nature of general intelligence.

7. Intelligence tests provide quite good, but imperfect, prediction of academic achievement. A good intelligence test such as the Stanford-Binet will sample widely from the range of intellectual tasks that can reasonably be used in a testing situation. The wider this sampling, and the more closely the particular mix of components sampled resembles the mix of components required in academic achievement, the better the prediction will be. A vocabulary

test, for example, will provide quite a good predictor of academic achievement, because academic achievement is so strongly dependent upon acquisition, transfer, and retention components, and upon the metacomponents that control them. A spatial test will probably be a less good predictor of general academic performance, because the performance components sampled in such a test will not be particularly relevant to general academic achievement, such as that required in shop or mechanics courses. An abstract reasoning test will probably be better than a spatial test, because the particular performance components involved in these tasks seem to be so general across tasks requiring inductive reasoning, including those found in academic learning environments. All intelligence tests will necessarily be imperfect predictors of academic achievement, however, because there is more to intelligence than is measured by intelligence tests, and because there is more to school achievement than intelligence.

8. Occasionally, people are quite good at one aspect of intellectual functioning, but quite poor at another. Everyone knows of people who exhibit unusual and sometimes bizarre discrepancies in intellectual functioning. An extremely mathematically inclined person may have trouble writing a sentence, or an accomplished novelist may have trouble adding simple columns of numbers. In the componential framework, the discrepancy can be accounted for in either of two ways. First, the discrepancy can be accounted for by inadequate functioning of or inadequate feedback from particular class components. The discrepancy cannot be in the general components, since they are common to all tasks, nor can it be in the specific components, because they apply only to single tasks. Hence, the discrepancy must be found in those class components that permeate performance of a given set of tasks, such as mathematical tasks, verbal tasks, or spatial tasks. Note that in contrast, someone whose intel-

lectual performance is generally depressed is more likely to be suffering inadequacies in execution of or feedback from general components (and possibly, class components as well). Second, the discrepancy can be accounted for by difficulty in operating upon a particular form of representation. Different kinds of information are probably represented in different ways, at least at some level of information processing. For example, there is good reason to believe that linguistic and spatial representations differ in at least some respects from each other (Sternberg, in press - b). A given component may operate successfully upon one form of representation but not upon another, as discussed earlier.

9. Intelligence is a necessary but not sufficient condition for creativity. Creativity, on the componential view, is due largely to the occurrence of transfer between items of knowledge (facts or ideas) that are not related to each other in an obvious way. In terms of the conceptualization in Figure 1, creative ideas derive from extremely sensitive feedback from and to transfer components. Such feedback is more likely to occur if, in acquisition, knowledge has been organized in a serviceable and richly interconnected way. But for interesting creative behavior to occur, there must be a rather substantial knowledge base so that there is something from and to which transfer can occur. Thus, for creativity to be shown, a high level of functioning in the acquisition, retention, and transfer components would seem to be prerequisite. These high levels of functioning are not in themselves sufficient for creativity to occur, however, since a sophisticated knowledge base does not in itself guarantee that the knowledge base will be used in sophisticated feedback to and from the transfer components. This mechanism is not intended to account for all creative behavior, nor even to give a full account of the creative behavior to which it can be applied. It does seem like a start toward a more detailed account,

however.

This componential view is consistent with recent research on expert-novice distinctions that suggests that a major part of what distinguishes experts from novices is differences in the knowledge base and its organization (e.g., Chase & Simon, 1973; Glaser & Chi, Note 4; Larkin, Note 5). The view is also consistent with that of Horn (1979), who has suggested that understanding of creativity may be better sought through an understanding of crystallized ability than through an understanding of fluid ability. Our previous failures to isolate loci of creative behavior may derive from our almost exclusive emphasis upon fluid abilities. The creativity tests that have resulted from this emphasis have measured what I believe to be rather trivial forms of creativity having little in common with the forms shown by creative novelists, artists, scientists, and the like. Research on transfer may be more likely to help us understand creativity than has the research on fluid ability tasks that has characterized most past inquiries.

10. Speed and accuracy (or quality) of intelligent performance may be positively correlated, negatively correlated, or uncorrelated. The results of the "new wave" of intelligence research (e.g., Hunt et al., 1975; Sternberg, 1977) make it clear that speed of performance and quality of performance bear no unique relation to each other. In the analogies task, for example, faster inference, mapping, application, and response component times are associated with higher intelligence test scores, but slower encoding is associated with the higher test scores. This finding can be understood at a metacomponential level: Individuals who encode stimuli more slowly are later able to operate upon their encodings more rapidly and accurately than are individuals who encode stimuli more rapidly. Faster encoding can thus actually slow down and impair the quality of overall performance (Sternberg, 1979b). Findings such as

this one emphasize the importance of decomposing overall response time and response accuracy into their constituent components, since different components may show different relations with intelligent performance. These findings also show the importance of seeking explanations for behavior at the metacomponential level. As important as it is to know what the individual is doing, it is even more important to know why he or she is doing it.

The ten findings on intelligence discussed above provide only a very partial list of replicable findings in the literature on intelligence, but they cover sufficient ground to convey some sense of how the componential view accounts for various phenomena involving intelligence. The componential view can account for a number of other findings as well, but does not deal with all phenomena involving intelligence, broadly defined. Although the various kinds of components form the core of the proposed intelligent system, they are by no means the only sources of individual differences (Sternberg, in press - a). First, components act upon different informational contents (e.g., verbal, numerical, geometric), and the informational content can be expected to influence the efficacy with which components function in different individuals (Sternberg, 1977). Second, information can be presented in a variety of modalities (e.g., visually, orally, kinesthetically), and the modality of presentation can be expected to influence the efficacy of information processing (Horn, 1974). Finally, processing of information will be affected by a host of motivational variables, each of which can have a substantial effect upon performance (Zigler, 1971). Thus, the functioning of various kinds of components can be adequately understood only in the whole context in which they operate.

The componential view deals with intelligent behavior at a level of analysis that may be elucidating for some kinds of analyses of behavior, but

not for others. The view does seem to provide, however, a reasonably well specified alternative to certain other views of what intelligence is and how it is manifested. In particular, it can account for different factorial theories under a single theoretical framework, suggesting at least the possibility of a unified theory of intelligent performance.

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Footnotes

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[1]The "componential" viewpoint presented here is my own, largely idiosyncratic one. Other related viewpoints that might be labeled "componential" include those of Carroll (1976), Hunt (1978; Hunt, Frost, & Lunneborg, 1973; Hunt, Lunneborg, & Lewis, 1975), Pellegrino and Glaser (1979), and Snow (1979). Moreover, the heavy emphasis upon "metacomponential" functioning that characterizes my own viewpoint is consistent with and has been influenced by such metacognitive (but not necessarily componential) theorists as Brown (1978; Brown & DeLoache, 1978; Campione & Brown, 1979) and Flavell (Flavell & Wellman, 1977). These alternative viewpoints need to be considered in any full review of the literature on contemporary theorizing about the nature of intelligence, although the present article is not purported to serve even as a partial literature review. Useful recent reviews include those of Carroll and Maxwell (1979), Pellegrino and Glaser (1979), Snow (1979), and Sternberg (1979a).

[2]Research on the isolation of metacomponents from task performance is being pursued in collaboration with Bill Salter, and is summarized in Sternberg (1979c).

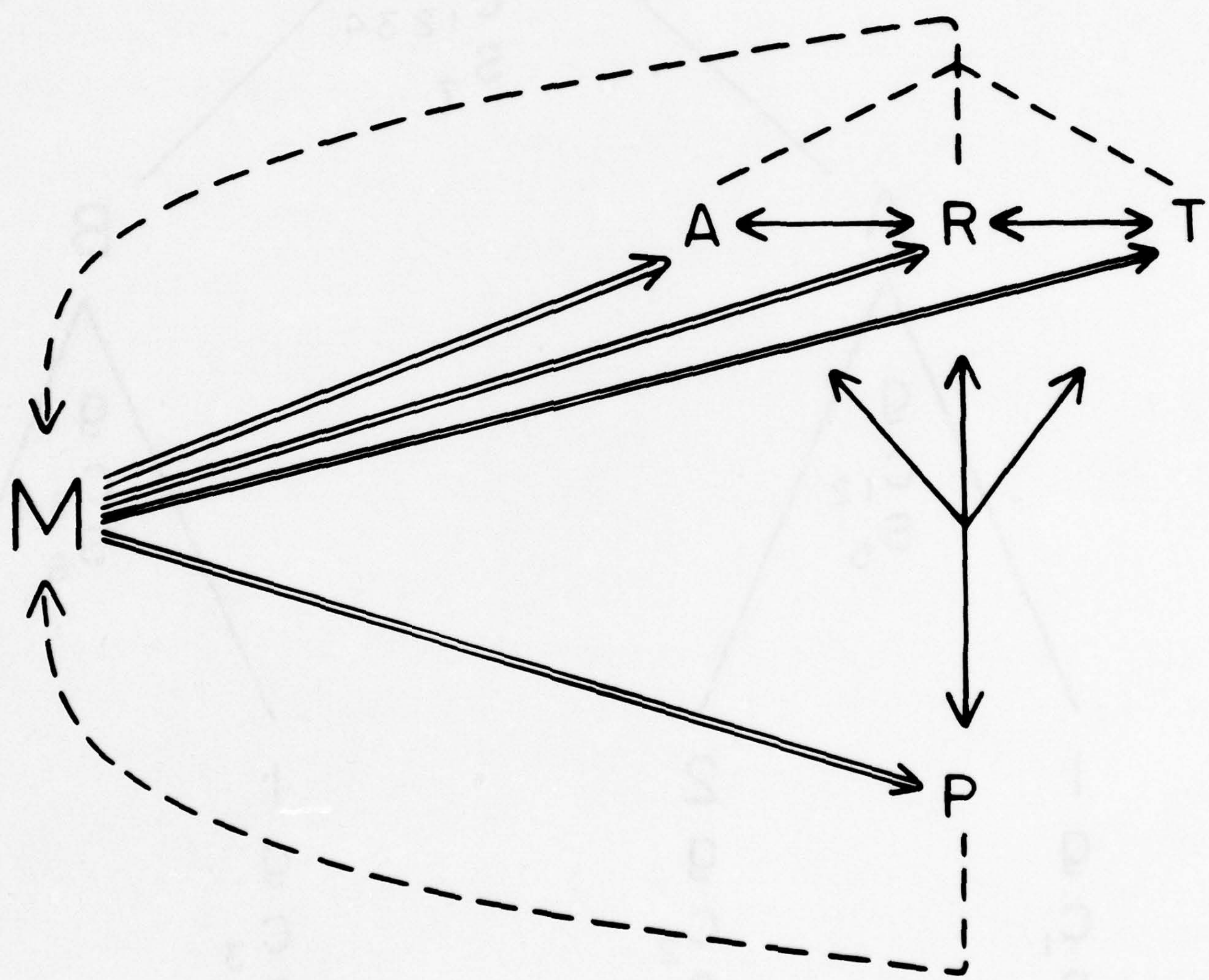
[3]In most of my earlier writings, I referred to performance components simply as "components."

[4]Research on the identification and isolation of acquisition, retention, and transfer components in everyday reading is being pursued in collaboration with Janet Powell, and is summarized in Sternberg (1979c).

Figure Captions

Figure 1. Interrelations among components serving different functions. In the figure, "M" refers to a set of metacomponents, "A" to a set of acquisition components, "R" to a set of retention components, "T" to a set of transfer components, and "P" to a set of performance components. Direct activation of one kind of component by another is represented by solid double arrows. Indirect activation of one kind of component by another is represented by single solid arrows. Directed feedback from one kind of component to another is represented by single broken arrows. Indirect feedback from one kind of component to another proceeds from and to the same components as does indirect activation, and so is shown by the single solid arrows.

Figure 2. Interrelations among components of different levels of generality. Each node of the hierarchy contains a task, which is designated by a roman or arabic numeral or by a letter. Each task comprises a set of components at the general (g), class (c), and specific (s) levels. In the figure, "g" refers to a set of general components; "c_i" and "c_j" each refer to a set of class components, and "c_{ij}" refers to a concatenated set of class components that includes the class components from both c_i and c_j; "s_i" refers to a set of specific components.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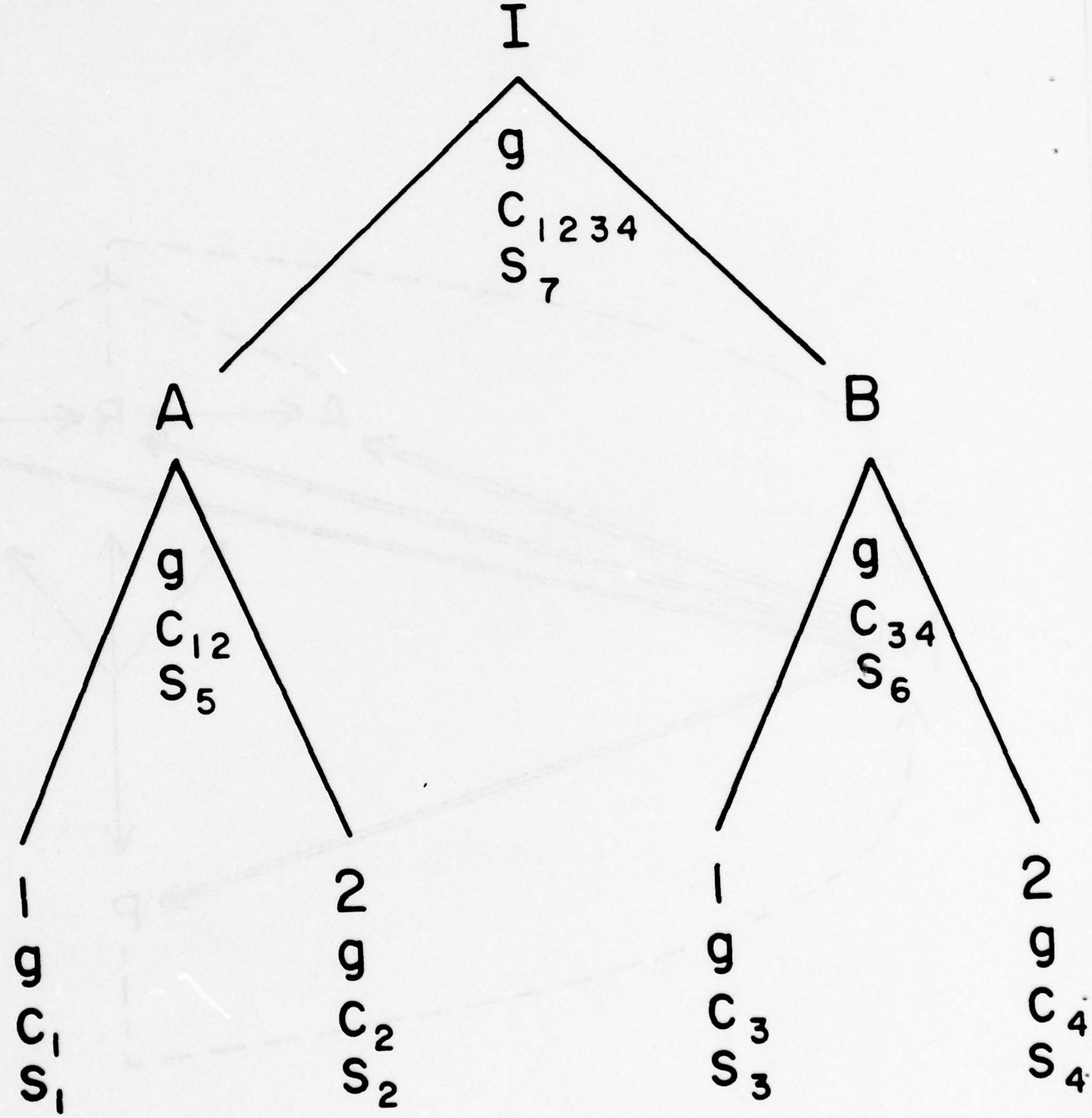

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